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ISSN: XXXX-XXXX

Springer
SPRINGER NATURE

1st Euro-Mediterranean Conference for Environmental Integration (EMCEI)

New Pathways in the Synthesis of 2-Dimensional Materials

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Highlights:

New advanced functional materials designed and engineered in a unique manner

Environmentally benign, rapid, single step synthetic capability

Effective solutions for energy, biomedical and environmental applications

Keywords: 2D, clean technologies, hydrothermal, supercritical, nanomaterials

The two-dimensional (2D) class of materials exhibit a wealth of remarkable properties (high surface area, high Young modulus, chemical stability, quantum confinement fluorescence) assigned to their atomic thickness and lateral dimensions. However, these materials standing alone do not possess the diversity of properties that are required to allow integration in a range of potential technological applications. Owing to the flexible and robust nature of these 2D nanosheets it is possible to design new 2D based functional materials with superior/new, tuneable properties from their parent 2D. This can be achieved *via bottom–up* (atom by atom growth) or *top-down* approaches (exfoliation of the corresponding 3D material reduced to give an atom thick monolayer 2D sheet)[1] and/or in combination with structural functionalisation.

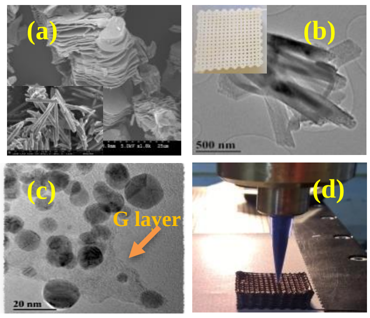
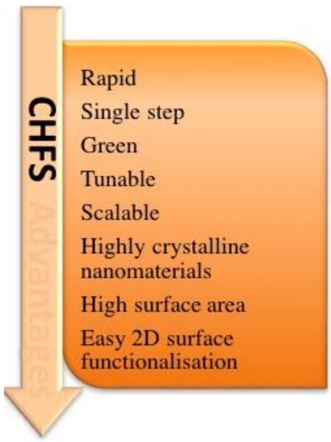


Fig. 1: Electron microscopy images of (a) MXene (inset Mxene rods), (b) h-BN and inset corresponding 3D printed compound, (c) Ag-graphene, (d) 3D printed graphene nanocomposites.



Our approach for making 2D based nanocomposites uses a clean, rapid technology as well as optimized traditional synthetic routes.[1-6] It potentially enables new advanced 2D inorganic nanocomposite functional materials designed and engineered in a more unique manner by using superheated water with unusual properties. It utilises a green, rapid and **Continuous Hydrothermal Flow Synthesis (CHFS)** route for synthesis of 2D-inorganic nanocomposites with superior properties to those currently available. CHFS is an environmentally benign, single step process that involves mixing (in a special reactor) a flow of superheated water with a flow of water-soluble precursor(s) to give controlled, continuous and rapid (within seconds) synthesis of nanomaterials (Fig.1). This system offers a variety of instant controls (temperature, pressure, residence time, reactant concentration) that allows a high degree of tailoring/functionalisation of the 2D materials (oxidation, composition, surface area, *etc.*) in their design to be fit for purpose. Less than 1% of hydrothermal methods reported in the literature employ CHFS as a route to material synthesis. The process is advantageous; it does not utilise a complex and lengthy process (is a continuous process), nor is potentially explosive (uses supercritical water) and limits the use of harmful, toxic chemicals (uses metal salts or biomass derivatives). This single step synthetic approach not only enables control over oxidation state of materials (*e.g.* graphene), but also offers an optimal route for homogeneously producing and depositing highly crystalline nanostructures into 2D-materials.

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Autobiography

Dr Suela Kellici is Senior Lecturer and head of the Nano2D group at London South Bank University (LSBU) [www.nano2d.co.uk]. Dr Kellici is an expert in innovative green supercritical fluid technologies and materials chemistry. She has a degree in Chemistry and PhD in Materials Chemistry (both from Queen Mary University of London). She then worked (3 years) on a successful EPSRC funded project at University College London, where she made extensive scientific contributions in combinatorial synthesis of nanomaterials. Dr Kellici sits on the Editorial Board for the Euro-Mediterranean Journal for Environmental Integration, she is Postgraduate Research Director for her School, Fellow of the Higher Education Academy and coordinator of outreach and PhD students related activities within LSBU and externally. Dr Kellici has been awarded several prizes for her work as well as recipient of financial awards from various funding bodies. The research in her group is focused in designing and discovering advanced functional nanomaterials (3D,2D, 1D and 0D) using a target-oriented approach and technologies that provide effective solutions for energy, biomedical and environmental applications.